Canadian Grain Commission
Commission canadienne des grains

Grain Research Laboratory

Annual Report 1990-91

Canada

GRAIN RESEARCH LABORATORY
64th Annual Report: 1990-91

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Cover Photo

Some of the breads that may be produced using flour milled from various classes of Canadian wheat.

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GRAIN RESEARCH LABORATORY
1990-91 REPORT

May 24, 1991

Canadian Grain Commission
Winnipeg, Manitoba

Commissioners:

I am pleased to submit the following report reviewing the activities of the Grain Research Laboratory for the period April 1, 1990 to March 31,1991.

Respectfully,

K.H. TIPPLES
Director

Introduction

The Grain Research Laboratory (GRL), the scientific division of the Canadian Grain Commission, has developed a world-wide reputation for its expertise in grain quality analysis. Together with the other divisions of the Commission, the GRL has contributed to the establishment of Canada's reputation as a consistent supplier of top-quality grains in both the domestic and international marketplace.

Quality assurance and **market support** for Canadian grain are the responsibilities of the Commission and also the basic objectives of the various service and research programs undertaken at the Laboratory. The foundation of Canada's grain quality assurance system is the intrinsic quality of the varieties of grain registered for cultivation - combined with the enforcement of stringent grain inspection standards. Since the grain inspection (grading) system is based on visual analysis of kernel condition, the GRL must relate chemical and physical quality factors, which indicate end-use value, to visually-assigned grades. As a result, today's grading system has evolved into a scientifically-based method of maximizing the amount of grain entering the higher grades, while at the same time protecting those grades from the effects of severe damage.

Grain Research Laboratory scientists and technologists help support the marketing programs of the Canadian Wheat Board and other grain exporters. Visits to current or potential customer countries are an important part of this process since they promote a dialogue regarding the quality and possible uses of Canadian grains. They also allow first-hand study of the customer's processing techniques which can then be simulated and modified at the GRL to produce optimum results. During these visits, problems encountered by processors in using Canadian grain may be investigated and solutions recommended. As well, the GRL is often host to foreign scientists and end-use processors who come to the Laboratory to learn and use Canadian processing or quality-testing procedures.

Appointments. Several people joined the professional staff this year: **Elizabeth Larmond** was named Deputy Director of the GRL; **Sandra HayGlass** was hired to fill the new position of Safety Officer; and **Michael Roscoe** assumed duties as a Chemist in the Residue Analysis section.

Congratulations! David Hatcher, a chemist in the Wheat Enzyme Research section, successfully defended his PhD thesis entitled "*Polyphenol Oxidase and Phenolic Acids - Their Levels and Influence in Canadian Wheat Flours*". David's research project was carried out at the GRL under the supervision of Dr. James Kruger, head of the section, and under the auspices of the University of Manitoba's Plant Science Department.

This year's report contains a feature section on the evolution of test baking at the Grain Research Laboratory. In it are described some of the various procedures, formulas and pieces of equipment that have been developed and used over the years to evaluate the breadmaking quality of flour.

Also included in this report is a short feature on workplace safety at the GRL - an increasingly important and time-consuming aspect of our everyday activities.

The permanent staff of the GRL totalled 113 at March 31, 1991. In addition, 15 casual assistants were employed for varying periods throughout the year, as well as three COSEP (career-oriented summer employment program) students.

Objectives and Operations of the GRL

The Laboratory Division of the Canadian Grain Commission has the broad **mandate**, under the Canada Grain Act (1971), to undertake **research into grain and grain products**. More specifically, this research and allied activities have as their major **objectives** the **quality assurance** and **market support** for Canadian grain. These objectives are attained through the wide range of interrelated programs outlined in Figure 1.

Quality assurance work begins long before a crop is seeded - with testing of new cultivars so that Canadian plant breeders can be advised whether their experimental lines will be suitable for registration. Harvest time brings with it tens of thousands of samples which are tested to determine the various quality parameters and degrading effects that will be representative of that year's crop. Ongoing surveys are carried out at critical stages of the shipping process to help ensure that every export package contains grain of uniform and consistent quality, free from unacceptable levels of toxic contaminants.

In many instances, quality assurance is a **joint effort** of the **Laboratory** and **Grain Inspection** divisions of the Canadian Grain Commission. The Commission's grain inspectors assign grades through a visual grading system, and it's the job of the GRL to ensure that the grade standards are relevant to the end-use quality and commercial value of the grain. As an example, although all registered varieties of red spring wheat are designed to have the best possible characteristics for bread production, factors such as weather and grain storage conditions can cause a deterioration in kernel appearance and subsequent lowering of grade. Laboratory scientists must determine the extent to which degradation in outer appearance corresponds to a decrease in quality or value.

In these times of subsidy wars that distort the relation between export grain price and true technological value, **market support** is extremely important in helping agencies such as the Canadian Wheat Board maintain a valuable marketing edge. It is imperative that we continue to enforce the concept that Canada's grain exports are of the highest quality and cleanliness, since buyers are continuing to demand **high and consistent quality** and raw materials that can pass the **strictest purity standards**.

The many **programs** which comprise Laboratory **operations** may be loosely categorized as research, related scientific activity or providing scientific and technical expertise - all of which are interrelated. **Research** provides the backbone of knowledge and information necessary to carry out the other aspects of operations. **Related scientific activities** provide data for quality monitoring or for production of market support adjuncts such as crop and cargo bulletins. **Scientific and technical expertise** supports the Commission and Inspection Division and allows authoritative and timely responses to customer enquiries. General commentaries on these programs and summaries of specific projects involved for 1990-91 are given in the three sections which follow.

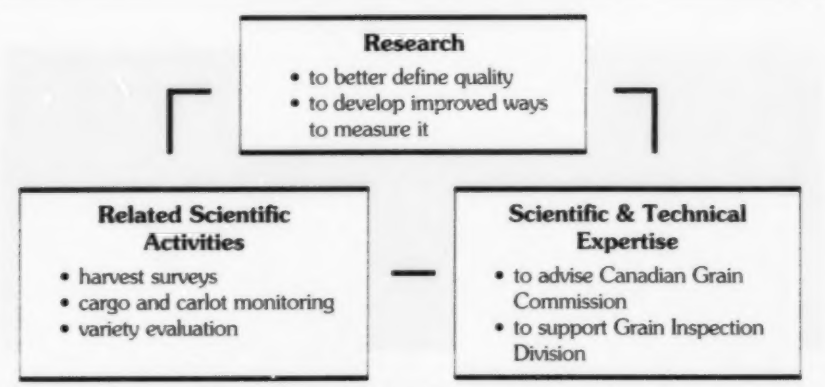

Research
• to better define quality
• to develop improved ways to measure it
Related Scientific Activities
• harvest surveys
• cargo and carlot monitoring
• variety evaluation
Scientific & Technical Expertise
• to advise Canadian Grain Commission
• to support Grain Inspection Division

Figure 1. Outline of Grain Research Laboratory programs and activities.

Quality Assurance Activities

Cargo and Carlot Monitoring

Throughout the crop year, the Canadian Grain Commission monitors rail carlots and cargo shipments of the various classes and grades of Canadian grains and oilseeds for certain quality determinants. The major aspects of this activity are screening and monitoring for toxic substances such as pesticides.

In response to the increasing demands of discriminating customers, the Laboratory has kept pace by increasing the allocation of time and resources to ensuring that Canadian grain is free from unacceptable levels of pesticides and mycotoxins. This work includes: input into decisions made on licensing of pesticides; monitoring of carlot unloads to determine freedom from admixture of seed-treated grain; and biological screening of cargoes for the presence of toxin-producing microorganisms and restricted weed seeds.

For the crop year ending July 31/90, a total of 1,426 cargo shipments of wheat, barley, oats, rye, canola, corn and soybeans were screened to confirm compliance with the strictest international tolerance limits for organochlorine, organophosphate and organonitrogen pesticide residues. Selected cargo shipments of wheat and barley were also monitored for the presence of phosphine and toxic elements. Samples representing one-hundred shipments of lentils were tested for the presence of diquat. All cargo shipments of Eastern Canadian wheat, corn and soybeans and selected export cargoes of Western Canadian grains were screened for mycotoxins.

As an additional quality assurance measure, one-thousand carlot unload samples representing deliveries of CWRS wheat into west coast terminal elevators were tested for malathion.

Due to continuing interest and concern about the possible presence of *fusarium* tricothecenes in grains grown in Southern Ontario, a total of 49 harvest survey samples of wheat, corn and soybeans were analyzed. During the same crop year, samples of 614 export cargoes of various grains were examined for potentially toxigenic fungi. Several cargoes of USA corn passing through Canadian elevators were also checked, particularly for fungi capable of producing aflatoxin.

All grain cargoes destined for the USSR, the People's Republic of China and Cuba were monitored for restricted weed seeds. These cargoes plus those of Eastern Canadian corn and soybeans and Western Canadian canola were analyzed to determine the occurrence and frequency of weed kinds found in Canadian exports. A geographic survey of restricted weed seeds in carlots arriving at terminal elevators continued for another year.

Samples of 77 cargoes (1.18 million tonnes) of canola were monitored for oil and protein content, fatty acid composition, free fatty acids, glucosinolates and chlorophyll level. In a new survey, feed barley cargoes shipped during the 1989-90 crop year were analyzed for several quality parameters, including protein and beta-glucan.

Michael Edney with flow injection analyzer for beta-glucan in barley.

Technical Services

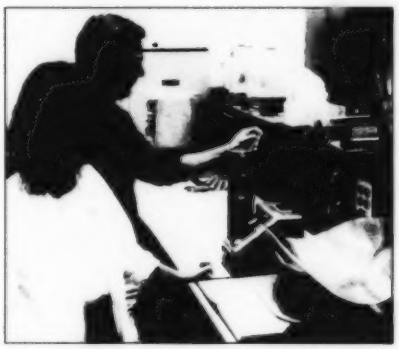
Most of the technical service work performed at the Laboratory is in support of the Commission's Grain Inspection Division. Quality enforcement teamwork between the two Divisions is manifest both in the official moisture test that is an integral part of grading and when chemical contamination is suspected. Commission inspectors submit carlot samples of grain they believe is tainted to the residue analysis laboratory which can detect and measure trace levels of pesticides, herbicides, mycotoxins and other toxic compounds in grain. Inspectors may also submit samples of wheat and barley to the GRL for confirmation of varietal identity by chemical analysis techniques.

Laboratory personnel calibrate and evaluate reflectance and transmission spectroscopy instruments used both commercially and at the Commission for wheat segregation according to protein content. As a technical resource, the GRL also serves other segments of the Canadian grain industry, including the Canadian Wheat Board, grain companies and processors.

The GRL is responsible for developing new and updated moisture conversion tables for Canadian grain, and must maintain the accuracy of all moisture meters used at the Commission for grading. A biweekly check test of the Model 919/3.5 moisture meter was carried out for 153 CGC and 43 industry meters. Meters recalled for servicing and electronic alignment during 1990-91 numbered 79. A performance survey of industry meters in use at country elevators throughout Western Canada was performed on location by Laboratory personnel.

The following seven moisture conversion tables for use with the Model 919/3.5 moisture meter were issued this year:

- Amber Durum Wheat
- Eastern White Winter Wheat
- Eastern Red Wheat
- Canada Prairie Spring Wheat
- Yellow Mustard
- Oriental Mustard
- Brown Mustard



Bob Wallis and Josie Kopilas using the Model 919 moisture meter.

Grading Factor Studies

Grading involves more than just the aesthetic appearance of the kernel. A detailed knowledge of how visual characteristics relate to processing quality is crucial to setting realistic tolerance levels for specific degrading factors such as immaturity, frost, weathering and insect damage. The Commission's Laboratory and Inspection divisions work closely to determine the effects of different percentages, intensities and types of damage on the grain's end-use value.

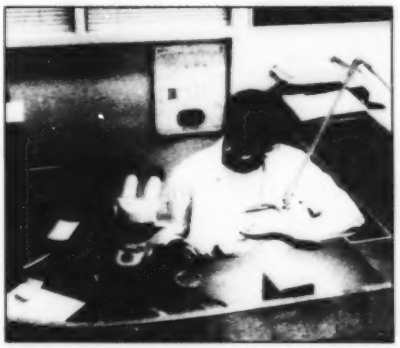
In the grain biology section of the GRL, visual support tools such as high-powered microscopes and computer assisted image enhancement and analysis are used to study grading factors for many different grains. Such techniques and equipment help provide a more scientific basis for visual inspection.

Experiments into the specific gravity segregation of grain were continued with application to wheat. Analysis of sound fractions recovered from parcels containing damaged kernels revealed that quality improved significantly over that of the original parcel. For example: test weight and thousand-kernel weight increased; milling yield increased; tombstone kernel percentage and alpha-amylase activity decreased; physical dough properties strengthened; and bread and pasta quality improved.

Mycological analysis of 1990-grown soybean from Ontario revealed unusually high levels of *Fusarium*, *Phomopsis* and downy mildew infections in some samples. All these instances were attributable to wet harvest conditions. The potential for a serious outbreak of fusarium head blight in Canada Eastern White Winter wheat faded with the advent of dry weather in June, the time when this crop is most susceptible to infection. Potential for an outbreak was believed to be present in Manitoba grains as well, since some fields were found to have high levels of the disease. However, it was not widespread in the area - likely due to the limited precipitation in July. Fusarium head blight was also detected in southern Alberta, but the causal species differed from those responsible for the disease in Ontario and Manitoba. It is likely that the affected Alberta fields were grown under irrigation.

Canadian Grain Commission grain inspectors in Chatham, Ontario initiated a project to evaluate sprouting damage in Canada Eastern white winter wheat. The inspectors selected and grouped sprout-damaged kernels exhibiting various degrees of germination. Photographs, of both grouped and individual kernels, will be compared with alpha-amylase activity values for each kernel to determine whether particular visible symptoms can be related to low or high levels of enzyme.

Research to determine the specific identity of wild sunflower seeds found in Western Canadian grain has been completed. The restricted weed species *Helianthus petiolaris* (prairie sunflower) can now be distinguished from the common *Helianthus annuus* (wild annual sunflower) by achene (seed shell) characteristics and confirmed by a specially adapted electrophoretic technique. These techniques have been used to study the origin and distribution of each species in prairie grain fields.



Seed analyst Karen Bell in the Grain Biology section.

Electrophoresis was investigated as an aid to grading French dark speckled lentils grown in Manitoba for export markets. Samples of these dark, mottled lentil seeds contained a flat-seeded form of *Vicia sativa* that was nearly identical in appearance. Either conventional or PhastSystem electrophoresis quickly and reliably distinguished between the lentil and the vetch.

Work is continuing on the prediction of Falling Number values using near-infrared spectroscopy. Correlation coefficients of 0.85 to 0.93 have been achieved with reflectance instruments and 0.63 to 0.84 with transmittance. Calibrations have also been developed for the Tecator Infratec Model 1225 transmittance analyzer for the determination of moisture in hard red spring wheat, soft white winter wheat, amber durum wheat, barley, oats, corn, soybean, canola, pea beans and red kidney beans.

Cultivar Evaluation

In Canada, varietal control is the major factor behind grain quality. Before registration is possible, a new cultivar must undergo years of testing for agronomic performance, disease resistance and end-use quality (Figure 2). For any given class, only varieties that fall within a relatively narrow range of quality are eligible for registration, and only those that can be visually class-identified will be supported.

From up to 40 000 initial crosses, only a few promising lines are entered in the Cooperative Test, where the GRL and other laboratories check for end-use quality. The Prairie Registration Recommending Committee for Grain (PRRCG) then considers data from its evaluation teams before recommending that Agriculture Canada register a variety for distribution. The Grain Research Laboratory has always contributed a large measure of expertise to quality evaluation work, and currently has nine scientists representing it on PRRCG evaluation teams.

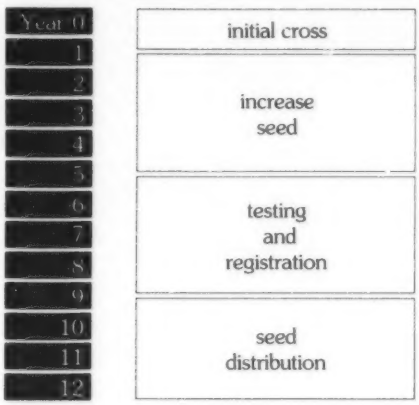


Figure 2. Example of the time required to release a grain variety in Canada.

This year's wheat variety evaluation program at the GRL required quality data to be generated for 171 entries in eight cooperative test series (Figure 3). At the 1991 meeting of the PRRCG, the various subcommittees supported registration applications for 5 potential new varieties in 4 wheat classes (Figure 4). Seven barley and 6 canola cultivars were also recommended for variety status.

Co-op Test	No. of lines evaluated
Red Spring	
Central	25
Western	25
Parkland	25
Amber Durum	20
Red Winter	
Lethbridge	24
Saskatoon	16
High-yielding (CPS)	16
Soft White Spring	20

Figure 3. Wheat variety testing at the GRL for 1990-91.

A program to help plant breeders improve the quality of Canadian feed barley has been initiated in the Laboratory's feed grain section. In addition to analyzing hull-less, two-rowed and six-rowed barley entries in cooperative tests for several different physical and chemical properties, projects will also focus on trying to determine what actually constitutes quality in feed barley.

To help gain a better understanding of the needs of plant breeders, the feed grain scientist, Dr. Edney, visited several feed barley breeding facilities across the Canadian Prairies. Useful ideas for the feed barley evaluation program emerged from the resulting discussions with the breeders, and as the parameters that best describe quality are determined, a quality screening system will evolve.

- 5 wheat varieties
  - 1 red spring
  - 1 soft white spring
  - 1 CPS (red)
  - 2 red winter
- 7 barley varieties
  - 2 two-rowed malting*
  - 2 six-rowed malting*
  - 3 feed
- 6 canola varieties
  - 3 *brassica napus*
  - 3 *brassica campestris*

* includes 1 for interim registration

Figure 4. Number of varieties receiving registration support in 1991.

Market Support Activities

Harvest and Cargo Surveys

One of the Grain Research Laboratory's most important market support roles is to provide crop quality information to Canada's grain industry and overseas customers. Therefore, surveys of the average quality of different grades of the various classes of Canadian grains and oilseeds harvested each growing season continue to be a major endeavor of the GRL (Figure 5). Again this year, all surveys were completed in time to present reports at meetings of the Eastern and Western Grain Standards Committees of the Canadian Grain Commission, at meetings held between grain industry groups and associations in Eastern Canada and the Canadian Grain Commission and at meetings and discussions held during overseas market support visits.

Harvest survey test results are also promptly made available in the form of a series of bulletins which provide an early indication of crop quality. The Canadian Wheat Board (CWB) has indicated that these publications are an important information tool for the Board in its ongoing communications with customers - particularly newer ones who may be less familiar with Canada's grading system and thus require specific quality information when making their buying decisions. The Canola Council of Canada, malting companies, and grain brokers, among others, use Laboratory crop bulletins in their dealings with customers. Publications on the 1990 survey were distributed internationally for wheat, feed barley, malting barley, canola, flaxseed and soybean.

Lawrence Morris with some of the thousands of harvest survey samples.

Quality testing of cargo composite samples remains a high priority and the following cargo bulletins documenting the high quality of Canadian grain exports were published and distributed to interested parties throughout the world: *quarterly editions* for red spring wheat, *semi-annual editions* for amber durum wheat and an *annual edition* for canola and flaxseed.

A *semi-annual analysis* of cargo composites of the following wheat classes was also continued: Canada Western Red Winter, Canada Prairie Spring, Canada Western Soft White Spring, Canada Western Utility and Canada Eastern White Winter. In addition, a *monthly analysis* of canola and an *annual analysis* of feed barley cargo composites were completed.

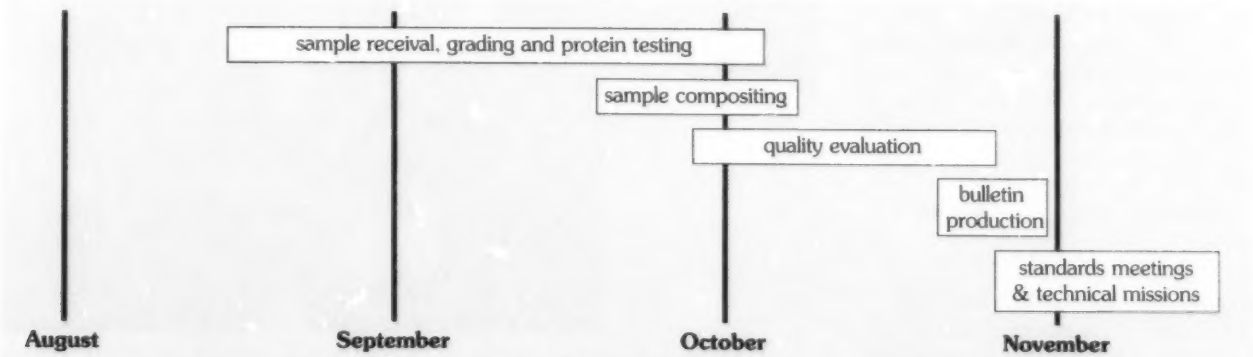


Figure 5. Outline of the activities involved in a typical GRL harvest survey for wheat.

Technical Consultations, Missions and Studies

The Laboratory director and scientists are active in the marketing support programs of the Canadian Wheat Board and other grain exporters by participating in a number of consultations and missions. Visits to an established or potential market area usually require describing to customers the quality and uses of Canadian grains, studying their processing techniques on-site and discussing current quality testing procedures. It may also involve investigating any problems encountered by a processor in using Canadian grain. At other times, foreign trade missions journey to Canada to meet with official representatives of various facets of the grain industry.

This year, for example, Dr. Tipples participated in a CGC visit to Japan in November for discussions with government and industry representatives on the quality of the 1990 Canadian wheat, feed barley and canola crops. Dr. Preston was part of a CWB market development and sales initiative in Korea and the Philippines, and Drs. Dexter and Matsuo made a follow-up technical visit to the Philippines late in the year. Mr. Nowicki took part in consultative meetings held in Winnipeg, Ottawa and Regina between senior officials of the Japanese Food Agency, Canadian Grain Commission, Agriculture Canada and Saskatchewan Wheat Pool.

Cooperation between the GRL and the Canadian International Grains Institute (CIGI) continued at home and abroad. As part of many of CIGI's grain technology and marketing courses, numerous tours, lectures, seminars and practical laboratory demonstrations were presented by Laboratory experts. Dr. Dexter was a member of a joint CIGI/CGC/CWB marketing mission to Mexico. At the CIGI/CGC Taiwan-Canada Wheat Symposium conducted in Taipei, Drs. Matsuo and Dexter presented seminars on the characteristics of Canadian wheat. The seminars were provided for Taiwanese flour millers and were held at the China Grain Products Research and Development Institute.

In market-oriented research, a comparison of the quality of Canadian malting barley with commercial samples of malting barley from other countries was completed on behalf of the Canadian Wheat Board. Two new two-rowed varieties, *Manley* and *Stein*, performed extremely well in these trials. Manley successfully completed its second year of commercial plant-scale testing in 1990 and should help to expand the growing area of two-rowed malting barley into eastern Saskatchewan and Manitoba. As background information for the possible redefinition of canola, a report on glucosinolates was prepared for the marketing committee of the Canola Council of Canada.

Bob Matsuo (left) at the Taiwan-Canada wheat symposium

Jim Dexter (2nd from left) discusses wheat quality with Mexican flour millers. Tony Tweed of CIGI is on the far right.

Research Activities

Wheat

A **study of flour fluorescence as a refinement predictor** revealed that measuring pericarp contaminant fluorescence is more effective than measuring aleurone contaminant fluorescence. The former procedure gives high correlations with the established flour refinement indices of ash content and color for GRL pilot mill flour streams from a given wheat. The relation is influenced by wheat class but not flour age, and was found to be homogeneous for No. 1 CW red spring wheat samples from three different years. In another milling project, it was observed that **cookie quality deteriorates as flour particle size decreases and extraction rate increases**. This implies that coarser flour sieve clothing can be used for soft wheat milling when cookie quality is being evaluated - greatly shortening the flow and increasing sample throughput without sacrificing extraction rate. The millflow is currently being modified further to also produce a patent cake flour.

Instruments for rapid measurement of sprouting damage continue to be assessed. The Ektochem DT system employing Kodak slides containing a starch substrate was compared with other methods such as Falling Number, Rapid Visco Analyzer and nephelometric alpha-amylase assay.

Because of the **importance of polyphenol oxidase enzymes and endogenous phenolic compounds in affecting the color of dough used for preparing noodles**, a comprehensive investigation of the levels of these components in mill streams of CWRS, CWSWS, CPS and CWRW wheat was undertaken. It is postulated that these indices may assist in prediction of optimal milling extraction rates for production of good quality noodles.

The **quantitative analysis of high molecular weight glutenin subunit 7** was carried out as part of the long-term objective of determining the relationship between wheat proteins and quality. Preliminary studies indicated that there was some variation in the electrophoretic mobility and quantity of this subunit in different varieties. Some Canadian varieties having this subunit also exhibited greater dough strength. Therefore, electrophoresis and high-performance liquid chromatography (HPLC) were used to characterize, qualitatively and quantitatively, this subunit in a series of Canadian wheat varieties and breeders' lines.

Results from **studies on the effect of oxidants on bread quality and oven spring, when the Canadian short process is used for baking**, indicate that all oxidants tested (ADA, iodate, bromate and ascorbic acid) had very similar effects on both bread quality and oven spring - when used at optimum levels. The **baking response to bromate of individual streams of flour milled from CWRS wheat on the GRL pilot mill** was also studied. Low grade and break flours required higher bromate levels than early and middle reduction streams to give optimum response.

In durum wheat research, **textural optimization studies of spaghetti using response surface methodology to determine the effects of drying temperature, protein level and amber durum semolina/red spring farina blends** have been completed. Work is now underway to refine the technique for instrumental measurement of cooked spaghetti surface stickiness.

Research into **cadmium levels in Canadian wheat** are continuing. Initial indications are that concentrations in Canada Western amber durum wheat are affected by both growing location and variety.

Barley and Feed Grains

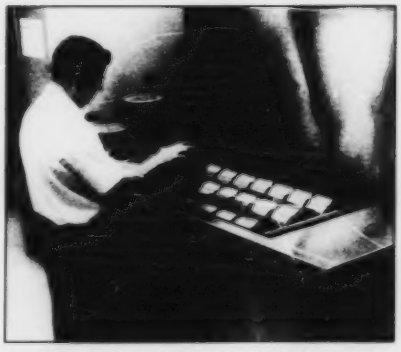
A **Phoenix Automated Micromalting System, designed to malt twenty-four 500 g samples per run**, was received, set up and made fully operational. This equipment increased the capacity of the GRL to malt larger numbers of samples and enabled the harvest survey for malting barley to be expanded. **Two flow injection analyzers for measuring viscosity and beta-glucan content** were also installed - allowing the incorporation of these methodologies for the first time at the GRL to evaluate the malting quality of breeders' advanced lines of barley.

Studies on the **starch degrading enzymes of barley and malt** were continued. The two major alpha-amylases in barley malt were shown to differ in starch-hydrolyzing efficiency. This difference could be attributed to small changes in the amino acids at the active centers of the two alpha-amylases. Commercial samples of malting barley with poor germination characteristics after storage were found to contain significant levels of germination-type alpha-amylases. These results indicate that the samples had sprouted, although this was not always obvious from visual inspection. Therefore, the viability of lightly sprouted barley kernels may decrease significantly during storage.

The **pattern of movement of cell wall degrading enzymes within barley endosperm during initial stages of germination** was studied using various microscopy techniques. The pathways used by these enzymes to move into and through the endosperm during malting were observed.

Canadian barley varieties were monitored for trypsin inhibitor activity since this has often been suggested as the cause of poor protein digestion in animals fed barley-based diets. Results indicate that the activity of this inhibitor is very dependent on variety and somewhat affected by environment. Two distinct trypsin inhibitors have been detected using electrophoresis.

An **automated method for measuring the color of Canadian feed barley** has been developed and preliminary results show an excellent correlation between the measurements obtained and visual scores. It is hoped that this method will help plant breeders develop a brighter Canadian barley.



Art Mitchelson operates the Phoenix automated micromalting system.

In order to help **determine what actually constitutes quality in feed grains**, a large number of samples were analyzed for beta-glucan, starch, protein, density and various fibre components. This information will be used to determine current quality characteristics of Canadian feed grains, and help to improve quality in the future.

A **multi-year study, in conjunction with the Universtiy of Manitoba Plant Science Department, on the effects of weathering on the quality and vigor of barley (and wheat) seeds** was completed this year. It was found that field weathering increases the probability of seed vigor loss, with barley more sensitive to this effect than wheat. Other seed characteristics affected were: bulk density, kernel density, hardness (wheat), alpha-amylase activity and microbial infection. Some of the negative effects could be reduced by straight combining.

Oilseeds

Two collaborative projects with the University of Manitoba were completed this year on canola: **chlorophyll content was found to be affected by both variety and environment** (with the Department of Plant Science); and **drying under humid conditions caused a reduction in chlorophyll levels** (with the Department of Agricultural Engineering).

With the cooperation of Canadian canola crushers, a study was **initiated to determine the effects of different processing steps on the breakdown of individual glucosinolates**. Findings to date suggest that the deodorizer toaster step is critical for glucosinolate destruction, that indolylglucosinolates are rapidly destroyed during processing and that the amount of glucosinolate destroyed during processing varies greatly with crusher.

Analysis, by NIR spectroscopy, of chlorophyll, oil and protein in harvest survey canola enabled documentation of the range in values for producer delivery samples. A strong correlation between oil and protein content was also noted.

Various sediments in canola oils were analyzed and found to be made up of wax esters, hydrocarbons, free fatty acids and alcohols. The compositions of the individual components were also determined.

In an experiment using an image analysis technique, **seed size differences between several varieties of canola were found to be too small to relate to quality differences**.

The **determination of the frequency and distribution of seed-borne fungi in canola, lentils and Canada Eastern white winter wheat** is an ongoing project. The resulting data base will be useful for answering enquiries as to toxin risks and disease distribution in grain.

Analytical Methodology

Institution of a high performance liquid chromatography (HPLC) method for the determination of glyphosate in grains is proceeding. Upon completion of developmental work, the GRL will commence screening of selected cargo shipments. Other methods currently under development or consideration, for the detection of toxic substances in grain, include: HPLC approaches for ergot alkaloids, ochratoxin A, zearalenone, and aflatoxins; and a gas chromatography - mass selective detector approach for phenoxyacid herbicides.

Electrophoresis has proven to be an invaluable tool in the identification of wheat and barley varieties. Various procedures are used throughout the world for this purpose, and efforts at standardization are being made by organizations such as the International Seed Testing Association. A **study was performed to compare procedures used at the GRL with such standard methods**.

Michael Roscoe determines glyphosate in grain, using HPLC.

In canola analysis methodology, a collaborative study provided information on the **precision of the proposed International Standards Organiza ion method for chlorophyll determination**. An HPLC method for the determination of glucosinolate content has now replaced the gas-liquid chromatography procedure at the GRL. The HPLC method is more accurate and precise - especially for aromatic, indolyl and minor glucosinolates.

Calibrations have been developed for the **NIRSystems Model 6500 scanning spectrophotometer** for the prediction of starch, protein and soluble, insoluble and total dietary fibre in oat bran - with accuracy sufficient for quality assurance during oat bran preparation.

The **sample transport system of the Tecator Infratec Model 1225 NIT analyzer** is proving superior to gravity sample access, particularly for grains such as high-moisture corn, barley and oats. Another advantage is that smaller samples (*eg.* 100 g) can be accommodated with no apparent loss in accuracy.

The **"DISCRIM" discriminant analysis software** from Galactic Industries has been applied to the rating of hay on the basis of mould growth. With minimal input, "DISCRIM" provided a more effective rating of the hay samples, based on glucosamine, than conventional NIR prediction of glucosamine content.

The **LECO FP-428 total nitrogen combustion analyzer** has been evaluated for use with a variety of cereals, pulses and oilseeds. It provided fast (2.5 minutes), precise analysis with accuracy equal or superior to the standard macro-Kjeldahl procedure, particularly for oilseeds, and proved useful for the analysis of small (milligram quantity) samples.

Phil Williams introduces a sample into the Model 1225 NIT analyzer.

Principal Component Analysis/ Partial Least Squares (PCA/PLS) regression analysis was applied during NIR determinations of more complex constituents. Results showed that weighting factors generated during development of PCA/PLS calibration equations can realize valuable information concerning the influence and interactions of constituents on the determination of composition by near-infrared technology.

R.H. Kilborn
K.R. Preston
K.H. Tipples

The Evolution of the Bread Wheat Baking Test: Past, Present And Future

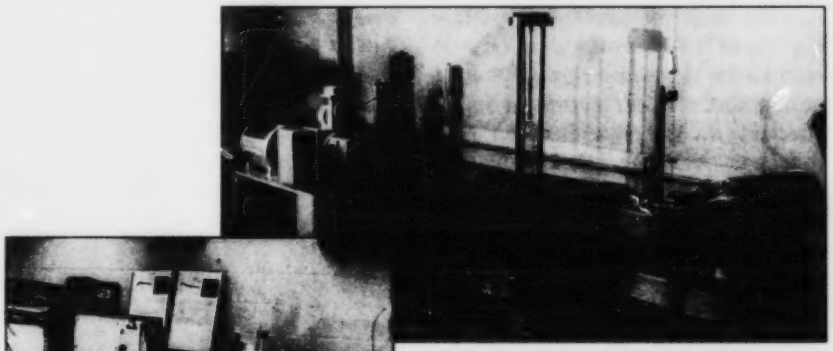
Anyone closely associated with the evaluation of wheat flour for bread production appreciates that the seemingly simple question "Is this a good bread wheat?" is complicated by the many permutations and variations of the baking process. That person is also aware that test baking can be very laborious and time consuming, and that it is a craft mixed with elements of art and science.

During the 77 years that the Grain Research Laboratory (GRL) has been in existence, the methods used to rank wheats for their bread making potential have undergone a number of changes. They have evolved from the concept that flours should be tested on their own merits by using a fixed straight dough process with an absolute minimum of added ingredients, to the principle that testing should involve the use of a range of tests employing a variety of formulations and processing conditions. This change in philosophy has taken place in response to a number of factors. These include an increased understanding of the role of ingredients and processing conditions and changes in commercial practice such as the introduction of short baking processes. As well, the expansion of Canada's markets has required that Canadian wheats have the flexibility to perform well over a wide range of conditions.

Equipment and instrumentation to carry out or assess the results of baking tests have also been constantly updated. The purchase and modification of commercial equipment and, in particular, the design and construction of laboratory-scale instrumentation by the GRL, have resulted in continual improvement in throughput and reliability of test bake results.

A straight-dough method with a minimum of added ingredients was used for many years for testing flour quality, although this evolved from a basic flour, salt, yeast, water formulation to one that included potassium bromate - then malt, ammonium phosphate and sugar. Loaf volume, the one objective measurement in test baking, can under some conditions be seriously affected if these latter ingredients are not present - in which case results would not reflect the full baking potential of the flour. One year in the early period of GRL test baking, flours milled from lower grade Canadian wheat gave markedly higher loaf volumes than flours milled from top grade wheat. At the time, it was not appreciated that the top grade wheat was so sound that it lacked sufficient alpha-amylase activity to convert damaged starch into the fermentable sugars required by yeast. This, in turn, meant that insufficient gas was generated to properly expand the dough at the proofing and oven stages. By contrast, the low grade samples contained some sprouted wheat which supplied the needed enzyme activity.

The addition of ammonium phosphate guaranteed the yeast a ready source of minerals and eliminated differences in water composition as a source of variability in the baking test. Some sugar was used to accelerate and sustain the fermentation and the concomitant working of the dough through gas production.



Dough rheology lab in the 1950's, showing (from foreground to background): farinograph, alveograph, extensigraph.

Present day "Remix" test setup - GRL pin mixer with energy-input meter and recorder attached.

Potassium bromate was usually added at levels of 0 and 10 ppm, although more detailed studies involved testing with amounts ranging from 0 to 25 ppm in increments of 5 ppm or 2.5 ppm, depending upon response. Increasing the amount of bromate increases the resistance of the dough to extension. A balance between extensibility and resistance to extension is required for optimum bread quality. The balance should be such that under a given process, the dough can expand (stretch) while having sufficient resistance to retain the gas which provides the force to stretch the dough. The straight-dough method is particularly sensitive to small changes in bromate level.

One baker, with occasional assistance, was able to handle the routine test baking through the 1940's. By 1950, an increase in the work volume demanded a full time technician work with the baker. A special oven for pup loaves had been designed and built, which eliminated heat-zone, atmospheric and loaf placement variables (1). The mixers used for routine test baking included the (small) C-10 Hobart with 2 dough hooks. The Swanson (mixer) attachment was used in methods calling for a more vigorous and intense mixing action. Neither mixer was water jacketed for temperature control, so tempered water or a pre-tempered mixing bowl was required. A fermentation cabinet controlled for temperature and humidity and engineered for uniform distribution of the conditioned air between shelves was developed (2, 1), and by 1955 the GRL 200 mixer (3) with a water-jacketed bowl had been developed. A water bath (1) to provide temperature control for yeast suspension, sugar-salt solution and dough water facilitated rapid transfer of these ingredients (with temperature assurance) to the mixing bowl. Mercury thermoregulators having a switching sensitivity of 0.1°C were used for sensing. These four pieces of equipment meant a significant improvement in comparability of data and increased throughput were achieved. Efforts were also made to control the bake room temperature, as it was realized that equipment such as sheeting rolls (having substantial heat-sinking capacity) influence dough temperatures at critical points in processing.

The Grain Research Laboratory was and still is required to test bake a large number of samples representing a wide range of breadmaking quality. Problems that arose in the past were partly related to the straight-dough method that was used. The sensitivity to bromate inherent in this method sometimes would require testing at different levels of bromate to optimize oxidation, involving more time than may have been available. Also, whereas the straight dough method tends to provide a reliable ranking of flour ranging in strength from weak to medium strong, further increases in strength tend to reduce loaf volume. Doughs from strong flours are not

Views of the "remix" baking test.

Harry Fisher hand moulding dough in the 1950's - with fermentation cabinet shown on the left.

Ed Mydlo places machine moulded "pup loaf" dough piece into pan.

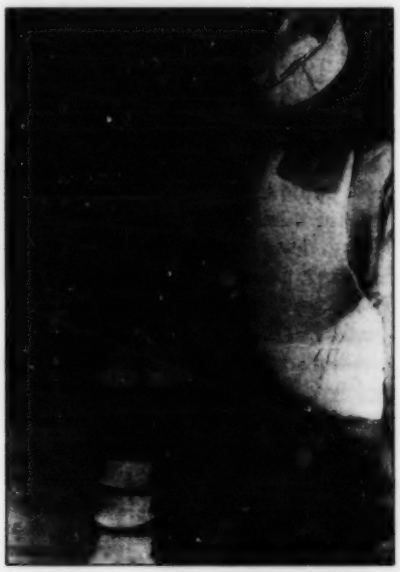
developed sufficiently and baking tests do not reproduce well. As a result, more replication than should be necessary may be needed to determine the "true" loaf volume, which, in any case, may not be a good indicator of performance for the flour being tested. In practice, even more variability might be expected because not all dough pieces can be processed at the same time and mixing and dough development conditions may differ.

The introduction of the GRL Remix Baking Method (4, 5) was the most significant contribution to reliability and efficiency in the routine test baking of relatively large numbers of samples. The need to vary bromate level was eliminated. The two stage mixing, separated by a vigorous fermentation, developed all but the extremely strong flours, and even these could be identified in the Remix Blend test (5, 6, 7) which was frequently carried out as a matter of routine. The Remix Method necessitated fewer repeat bake tests beyond the normal duplicate bakes on separate days. This method also made possible (much later, in 1973) a convenient indexing of protein quality, "The Baking Strength Index" (8).

The next step to increasing sample throughput was the development of a molder for test baking. Hand molding by an experienced baker was found to give greater differentiation between samples in terms of loaf volume and other loaf characteristics than did commercially available molders. While these machines can be adjusted to perform well for a specific type and quality of dough, the molding action is unsatisfactory for doughs that differ widely in gas retention and thus in

Ed Gander using the GRL Dough Sheeting and Moulding Property Indicator.

Research baking at the GRL.



Henry Kilborn (l) and Garth Paulley score crumb structure.

"bulk" size. The new laboratory-scale molder also helped overcome the variability in baking results obtained by different bakers or operators - a consequence of individual differences in manipulating the dough at the molding stage. The GRL molder automatically adjusts to the size (bulk) of the dough and applies the same pressure to all doughs processed in this way (9). Its introduction permitted an increase in the number of bakers capable of performing the Remix tests while maintaining comparability of data.

By the early 1960's, the GRL was operating both routine and research baking laboratories. The advent of short-baking processes in the USA (Amflow and Baker) and the UK (Chorleywood) required that the GRL become knowledgeable and experienced with these new baking systems as they related to Canadian wheat. A significant part of the research program involved the study of dough mixers and the phenomenon of dough development. Over a 10-year span, instruments and machines needed for these studies were designed and constructed. As a result of this research, two of us (RHK and KHT) were honored at the Sixth International Cereal and Bread Congress in 1978 with the Carl Wilhelm Brabender Award for contributions to the field of rheology as applied to the milling and baking industry.

Research centered around factors affecting the development of dough structure during bread making. Some basic concepts relating to mixing requirements for optimum bread

quality were formulated and provided insight into the dough formation process. The effect of mixing intensity and work input was studied using the GRL pin mixer and a laboratory-scale programmed dough-mixing unit, designed and built at the GRL. This also permitted examination of the effects of temperature and pressure on dough development (10). The research illustrated that "intensity" and "work level" were the two basic requirements for achieving properly developed doughs (11). The implications of mixing at a constant rate of energy input as opposed to conventional constant mixer speed were examined and it was demonstrated that mixing time could be reduced using constant energy (12).

In order to determine the mixing efficiency of various mixers, the mechanical efficiency of laboratory dough mixers was measured and found to vary from 40 to 80% (13). Therefore, the GRL energy input meter was redesigned to provide for "dialing in" of the mechanical efficiency of any given mixer. This, in turn, made possible automatic correction of mixing curves and work-input values so that net values could be reported and mixers could be compared directly without the complication of mechanical losses associated with each mixer (14, 6).

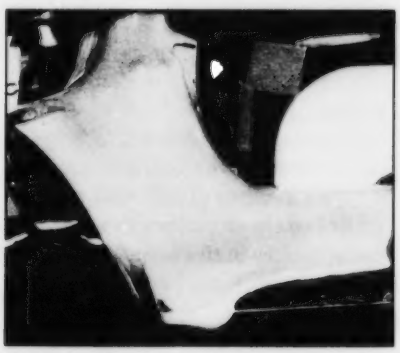
The effect of L-cysteine in reducing the mixing requirements for mechanically developed doughs was established for a range of flour strengths - demonstrating how earlier concepts relating to mixing intensity (critical speed) and work input (minimum critical level) could be applied to determining the amount of cysteine required to produce satisfactory bread (15).

In some countries, bakers make use of the dough brake, which consists of a pair of motor driven steel rolls having a variable gap (spacing) to develop bread dough. The dough is repeatedly fed through the gap of the sheeting rolls in order to work and stretch it. For studying the implications of mechanical development by sheeting rolls (16, 17), the GRL 1000 mixer (18) and a modified stand of sheeting rolls were used to compare each system of dough development. Comparable bread was obtained using the sheeting rolls, and only about 15 to 25% of the work required by the mixer was needed. It was concluded that much scope may exist for modification of mixer design to allow for the development of dough in a more efficient manner.

Discovery and study of the phenomenon of "Unmixing" (19, 20) triggered the postulation of the relationship between developed and undermixed dough, and consolidated concepts generated from earlier work on dough development. "Unmixing" is the apparent reversal of dough development brought about when a dough mixed to peak consistency at high speed is mixed for a further period of time well below the minimum speed required for optimum development. At the reduced speed the dough changes in character from a shiny, elastic mass capable of being stretched into thin sheets to a rough, lumpy mass lacking cohesiveness. Bread processed from such dough resembles bread obtained from a severely undermixed dough.

Undeveloped dough.

Sheeting.



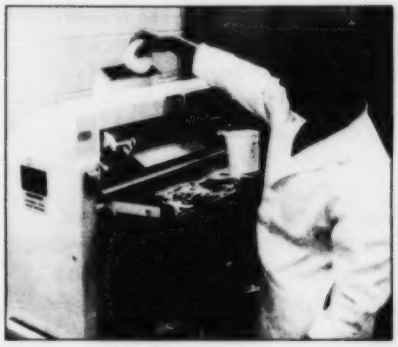
Fully developed dough.

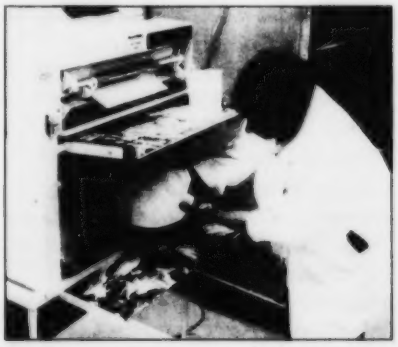
A look at the "Dough Brake" system of dough development.

All mixers impart two types of action that work against each other: stirring action, which may be considered as destructive to the formation of the sheet-like structure of dough, and stretching and working, which must be of sufficient intensity to overcome the detrimental effects of the stirring action in order to promote the formation of the laminar sheet structure. Sheeting rolls have no stirring action to negate the beneficial stretching and squeezing action, and therefore there is little wasted energy. Further studies have shown that mixer action may have some beneficial effects in "opening-up" the dough to atmospheric oxygen. By contrast, when dough is developed by sheeting rolls there is no appreciable atmospheric oxygen incorporated into it and any oxidation must come from added chemicals.

Research results were also published on the following topics: a mechanism for obtaining mixing curves from commercial mixers (21, 22), and features of bread processing of direct interest to the commercial baking industry (23, 24).

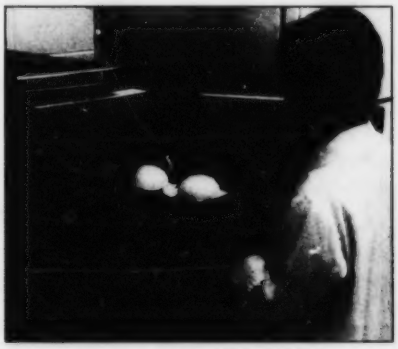
In the mid-1960's, changing markets for Canadian wheat prompted the addition of a technical services baking laboratory equipped with small-scale commercial equipment. In this laboratory, findings from the research laboratory could be scaled up and tried out on equipment usually found in small bake shops. As well, commercial processes could be scaled down and used to assess the performance of Canadian wheat under a variety of commercial formulations and processing conditions utilized in our export markets.





Ed Lysenko using a small-scale commercial dough moulder in the technical services baking laboratory.

Changing markets also influenced the extent of supplemental test baking used to examine harvest survey and plant breeder material. At present, the major tests are: the Remix Method and its variations, the sponge-and-dough procedure, and the Canadian short-baking process. The latter two involve using variable oxidation in some instances. The Canadian short-baking process testing procedure evolved from the GRL Chorleywood method (25), with changes that paralleled Canadian bakery formulation (26). The GRL sponge-and-dough method largely simulates the commercial sponge-and-dough method used in Japan. Research into sponge-and-dough formulation to reduce sponge time has proven successful (27, 28). Further studies of the Remix method related to the effect of fermentation time and salt level (29, 30). Results of investigations into the specific market requirements of Brazil and Colombia have been published (31, 32, 33). A study on the effect of flour type and extraction on Chinese steamed bread has also been reported (34).



Helena Facto with finished product. *Texture analysis of the crumb.*

Production and testing of Chinese steamed bread at the GRL.

Instruments developed at the GRL to study bread and dough properties include: the Compression Tester for measuring bread crumb deformation and resiliency (35) and stickiness of cooked spaghetti (36); the Dough Height Tracker for studying sponge rise and fall and proofing patterns associated with different flours and formulations (37); the Heat Sink Oven (38) which was developed as a reference oven after collaborative ICC (International Association for Cereal Science and Technology) baking tests (unpublished) indicated that differences in oven type and configuration were largely responsible for poor inter-laboratory results; and a Dough Sheeting and Molding Property Indicator (39) which provides objective and non-destructive measurements of extensibility, resistance to extension, work required for sheeting and an index of the gas retention of doughs at time of sheeting in baking tests. This latter instrument has been modified to provide results automatically in the form of a paper tape read-out in directly reportable units. Stretching properties of fermented dough were also studied using specially designed dough holders and modified extensigraph procedures (40, 29).

Recent studies have been directed towards increasing our understanding of the effects of oxidants and other improvers at particular stages of the baking process. Heat sink ovens were equipped with loaf height trackers to measure oven rise characteristics of doughs during baking (41). Additions of ascorbic acid and sodium stearoyl-2-lactylate (SSL) were required to optimize the quality of Brazilian hearth bread (41). The improving action of these ingredients was attributed to the effect upon oven rise which occurred over a longer period of time than when these "improvers" were not used. Development of desirable break and shred characteristics have also been shown to be associated with the improving action. Current preliminary results indicate that four common oxidants (ascorbic acid, potassium iodate, azodicarbonamide and potassium bromate) all produce similar improving effects in pan bread. These oxidants all increase the time during which dough expansion occurs in the oven.

In addition to continuing and expanding the preceding work described, greater emphasis will be placed upon the development of laboratory-scale tests which simulate commercial baking processes being used in our export markets. This research will be aimed at providing a better understanding of the wheat and flour requirements of present and potential customers - which should enable continued direction to be provided to Canada's plant breeders in the development of improved wheat varieties.

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Profile - Elizabeth Larmond

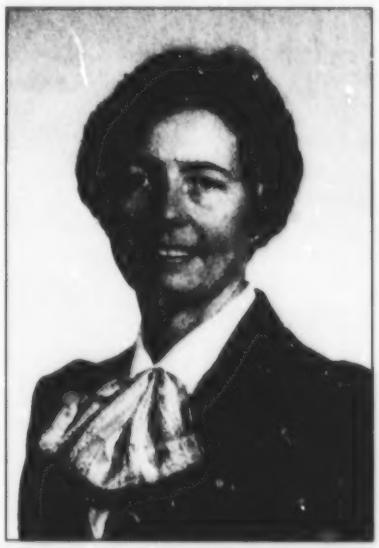
Elizabeth Larmond has enhanced the Grain Research Laboratory's senior management team since August, 1990, when she was appointed Deputy Director. In this capacity, Ms. Larmond will be responsible for the Laboratory's non-research scientific activities. In addition, she will review and update internal GRL management procedures as part of the short- and long-term planning process.

Ms. Larmond brings to this new position an extensive background in food science and management within Agriculture Canada. With a *BSc* degree (*magna cum laude*) from Mount Saint Vincent University in Halifax, she began her career in 1963 as a sensory evaluation scientist at the Food Research Institute in Ottawa. She is recognized internationally as a pioneering force in the field and has presented her research results in 57 refereed scientific papers and 31 miscellaneous publications. Training workshops for food processors have been conducted by her in several other countries.

From 1986 to 1990, Ms. Larmond coordinated the Department's food research program across Canada. Her responsibilities included developing research policies and matching priorities to the needs of Canada's food processing industry. She also prepared a wide variety of analytical reports and provided expert advice on food-related research management.

In 1989 she was made a Fellow of the Institute of Food Technologists (IFT) - nominated for her "significant contributions to the profession of food science, food research and research management". The following year she received the William J. Eva Award for outstanding research and service from the Canadian Institute of Food Science and Technology.

Ms. Larmond has been active on many committees in several scientific organizations, and has played a strong communications role as a lecturer and guest speaker to various industry groups.



Elizabeth Larmond

Workplace Safety at the GRL

Sandy HayGlass

Occupational health and safety has always been a priority at the Grain Research Laboratory (GRL). All staff commit considerable time to ensuring safe working conditions, and the GRL has its own advisory committee on safety in addition to playing a very active role in the Canadian Grain Commission's safety and health committee. In April of 1990, Ms. Sandy HayGlass was hired as the GRL's first full-time safety officer.

The safety programs are continually evaluated, improved and expanded in order to provide the safest possible working conditions for all staff. Tangible evidence of concern for safety may be seen in all renovations and new construction, and standardizing safety equipment purchases for all areas has become part of the safety program. Available emergency response equipment is also being evaluated and plans to upgrade emergency eyewash stations and showers have been implemented. All such facilities are tested every six weeks. Other new safety initiatives deal with procedures for handling potentially explosive substances and for transporting dangerous chemicals in the building.

Ensuring compliance with legislation is critical. In 1988, the Government of Canada enacted the Workplace Hazardous Materials Information System (WHMIS) under the Hazardous Products Act. The purpose of WHMIS is to ensure the safe manufacture, use, handling and storage of specified chemicals in the workplace. This is facilitated through a system of product labelling, product safety data literature and employee education programs - with the GRL providing a WHMIS training program.

An important responsibility of the safety officer is to act as a resource on topics such as proper chemical handling and disposal, equipment purchases and legislative requirements pertaining to workplace safety. In addition to distributing applicable information throughout the GRL, the safety officer assists other divisions of the Canadian Grain Commission in addressing specific safety concerns and WHMIS requirements.

Liaison Activities

Visitors and Visits

This year, 623 people visited the Grain Research Laboratory (GRL). Forty-seven of the visitors were from the following 13 countries: Australia, France, India, Japan, Korea, Mexico, New Zealand, Pakistan, People's Republic of China, Poland, United Kingdom, USA, USSR. Not included in the foregoing list are countries represented by participants in Canadian International Grains Institute courses which incorporate tours of the GRL. Canadian visitors included: 175 grain producers, 75 elevator managers, 81 students in degree or diploma courses in agriculture at universities or community colleges and 5 persons involved with grain marketing.

Dr. Yasushi Endo, holder of a travelling fellowship from the Natural Sciences and Engineering Research Council of Canada, began his term of study at the GRL this year. Dr. Endo is from the Department of Food Chemistry, Faculty of Agriculture at Tohoku University in Sendai, Japan and will be collaborating with Dr. J. Daun, head of the GRL oilseeds section. His research will include the development and evaluation of analytical methods for the determination of chlorophyll and other color bodies in oilseeds.

Three post-graduate students at the University of Manitoba are also undertaking research studies in the oilseeds section of the GRL: **Ms. June Hu** is continuing her project on waxes in canola seed; **Ms. Kerry Ward** has begun work on the effect of variety on chlorophyll in oilseeds; and **Mr. Rod Mailer** is working on the identification of canola varieties. Although studying at the University of Manitoba, Mr. Mailer is an employee of the New South Wales Department of Agriculture in Australia.

Ms. Linda Malcolmson, working with durum wheat section head Dr. R. Matsuo, completed her research and fulfilled requirements for the PhD degree at the University of Manitoba where she has now returned to teach. **Mr. Yuji Yamada**, a visiting scientist from the Yamazaki Baking Company in Japan, continued his breadmaking studies with Dr. K. Preston, head of baking research.

A four-month sabbatical was taken by **Dr. J. Kruger**, head of the GRL's wheat enzyme research section, at the Bread Research Institute of Australia in Sydney. The focus was to study test procedures used for the production of noodles, steamed bread and Arabic flat-breads. In addition, Dr. Kruger undertook a research project on the effects of sprout- damaged wheat on noodle quality. He also stopped in Bangkok, Thailand to observe techniques used in commercial flour mills and bakeries there.

It is important and beneficial that the Grain Research Laboratory maintain contact with the various elements of the Canadian grain industry. In support of this ideal, the following senior staff members participated in informational meetings or seminars involving (among others) producers, elevator managers, feed barley breeders, the Canadian Wheat Board, eastern Canadian grain industry associations or the Industrial Assistance Research Program: Drs. J. Daun, J. Dexter, M. Edney, J. Kruger, D. LaBerge, A. MacGregor, R. Matsuo, K. Tipples, P. Williams, Mr. T. Nowicki and Mr. L. Morris.

Rod Mailer (l) consulting with Jim Daun, oilseeds section head.

Committee Membership

Canadian Grain Commission
- Eastern and Western Grain Standards Committees ..... K.H. Tipples
- Steering Committee for Professional Interaction ..... T.W. Nowicki *(chairman)*
  L.A. Cooke

Agriculture Canada
- Advisory Committee on Variety Registration ..... R.R. Matsuo
- Expert Committee on Fats, Oils and Other Lipids ..... J.K. Daun
- Western Expert Committee on Grain ..... K.H. Tipples
- Prairie Registration Recommending Committee for Grain
  - Evaluation Team, Barley and Oats ..... D.E. LaBerge *(chairman)*
    A.W. MacGregor
    - Subcommittee on Oats Evaluation ..... A.W. MacGregor
  - Evaluation Team, Oilseed ..... J.K.Daun *(chairman)*
    D.R. DeClercq
  - Evaluation Team, Special Crops ..... R. Tkachuk
  - Evaluation Team, Wheat, Rye and Triticale ..... K.R. Preston *(chairman)*
    R.R. Matsuo
    P.C. Williams

Agricultural Institute of Canada
- Associate Editor, Canadian Journal of Plant Science ..... S.J. Symons

American Association of Cereal Chemists
- Technical Committees:
  - Amylase Methods ..... J.E. Kruger (co-chairman)
    A.W. MacGregor (co-chairman)
  - Bread Baking Methods ..... K.R. Preston
  - Experimental Milling ..... J.E. Dexter (chairman)
  - Methods for Grain Testing ..... P.C. Williams
  - Near-infrared Reflectance ..... P.C. Williams
  - Oat Bran ..... P.C. Williams
  - Pasta Products Analysis ..... J.E. Dexter
    R.R. Matsuo
  - Physical Testing Methods ..... K.R. Preston
  - Quality Tests for Wheat and Flour ..... R. Tkachuk
  - Total Dietary Fiber ..... P.C. Williams
  - Yeast Evaluation ..... P.C. Williams
- Canadian Prairie Section ..... J.E. Morgan *(secretary-treasurer)*
- Board of Directors ..... J.E. Kruger
- Board of Editors, Cereal Chemistry ..... B.A. Marchylo
- Editorial Advisory Committee, Cereal Foods World ..... J.E. Dexter

Milling and Baking Technical Conference (1990)
Program Committee ..... K.R. Preston
Osborne Medal Award Committee ..... K.R. Preston
Program Advisory Committee ..... J.E. Dexter
Publications Committee ..... J.E. Kruger

American Oil Chemists' Society
Annual Meeting (1992) Technical Program Committee ..... J.K. Daun *(chairman)*
Awards Administration ..... J.K. Daun
Canadian Section ..... J.K. Daun *(president)*
Seed and Meal Analysis Committee ..... J.K. Daun *(chairman)*

Association of Official Analytical Chemists
Mid-Canada Regional Section ..... T.W. Nowicki *(president-elect)*

Brewing and Malting Barley Research Institute
Technical Committee ..... D.E. LaBerge

Canadian General Standards Boards
Committee on Bakery and Cereal Products ..... R.R. Matsuo

Codex Alimentarius Commission, FAO/WHO
Canadian Delegation ..... R. Tkachuk *(chairman)*

Eastern Prairie Barley Group ..... D.E. LaBerge

European Brewing Convention Barley and Malt Group
Barley Quality Assessment Subgroup ..... A.W. MacGregor

Federal Interdepartmental Committee on Pesticides Check Sample Program
Feeds/Grains Sub-program ..... T.W. Nowicki *(co-ordinator)*

Flax Council of Canada
Market Development Committee ..... J.K. Daun
Research and Technical Committee ..... J.K. Daun

Group consultatif international pour la research sur la colza ..... J.K. Daun

Institute of Food Technologists
Committee on Constitution and By-Laws ..... M.E. Larmond

International Association for Cereal Science and Technology (ICC)
Executive Committee, Technical Committee and General Assembly ..... K.H. Tipples
Working Groups on:
Variety Identification by Electrophoresis ..... R. Tkachuk
Baking ..... K.R. Preston *(co-chairman)*

Determination of Wet Gluten ..... K.R. Preston
P.C. Williams
Particle Size/Wheat Hardness ..... P.C. Williams
Methods of Protein Determination ..... R. Tkachuk
Sampling ..... P.C. Williams
Near-infrared Technology ..... P.C. Williams

International Committee on Pre-Harvest Sprouting ..... J.E. Kruger

International Gluten Workshop (1990)
Organizing Committee ..... R. Tkachuk *(chairman)*
Wheat Protein Nomenclature Committee ..... R. Tkachuk *(chairman)*

International Rapeseed Congress (1992)
Program Committee ..... J.K. Daun

International Standards Organization
Canadian Advisory Committee TC34/SC4 ..... K.H. Tipples *(chairman)*
R.Tkachuk
Canadian Advisory Committee TC34/SC2 ..... J.K. Daun
Canadian Advisory Committee TC34/SC11 ..... J.K. Daun

Journal of Cereal Science
Board of Editors ..... K.H. Tipples

Journal of the Institute of Brewing
Editorial Board ..... A.W. MacGregor

Manitoba Sunflower Committee ..... J.K. Daun

Master Brewers' Association of the Americas
Housing Committee - District Western Canada 1992 Convention ..... D.E. LaBerge *(chairman)*

Natural Sciences and Engineering Research Council of Canada
Industrial Research Assistance Program (IRAP)
Development of Quality Malt Using Analogs of Abscisic Acid
Scientific Advisor ..... D.E. LaBerge

Red River Community College
Advisory Committee for Chemical and Biochemical Technology ..... R. Tkachuk

Statistical Society of Canada
Regional and Society Cooperation ..... J.C. Babb *(chairman)*
Board of Directors ..... J.C. Babb
Public Relations ..... J.C. Babb

University of Guelph
Adjunct Professor ..... P.C. Williams

University of Manitoba
Adjunct Professors ..... J.K. Daun
J.E. Kruger
A.W. MacGregor
R.R. Matsuo
R. Tkachuk
P.C. Williams

Winnipeg Brewmasters Association ..... D.E. LaBerge *(chairman)*

Conference and Meeting Attendance

Agriculture Canada
Advisory Committee on Variety Registration
Meeting in Ottawa, ON ..... R.R. Matsuo
Expert Committee on Fats, Oils and Other Lipids
1990 Meeting, Toronto, ON ..... J.K. Daun
Western Expert Committee on Grain
1991 Meeting, Calgary, AB ..... K.H. Tipples
Prairie Registration Recommending Committee for Grain
1991 Meeting, Calgary, AB ..... J.K. Daun
M.J. Edney
D.E. LaBerge
R.R. Matsuo
K.R. Preston
K.H. Tipples
R. Tkachuk
P.C. Williams
Western Computers Users Meeting
Calgary, AB ..... R. Tkachuk

American Association of Cereal Chemists
Annual Meeting, Dallas, TX ..... J.E. Dexter
V.J. Mellish
K.H. Tipples
P.C. Williams
Eastern Canada Section Meeting
Toronto, ON ..... K.R. Preston
Milling and Baking Technical Conference
Denver, CO ..... F.G. Paulley

American Oil Chemists' Society
- Annual Conference, Baltimore, MD ..... J.K. Daun, J.A. Panford
- Canadian Section Meeting, Toronto, ON ..... J.K. Daun
- Seed and Meal Analysis Committee
  - Meeting in Toronto, ON ..... J.K. Daun

American Statistical Association
- Annual Meeting, Anaheim, CA ..... J.C. Babb

Association of Official Analytical Chemists
- International Meeting, New Orleans, LA ..... T.W. Nowicki

Association of Official Seed Analysts/Society of Commercial Seed Technologists
- Joint Meeting, Annapolis, MD ..... L.A. Cooke

Association of Operative Millers
- Annual Conference, Orlando, FL ..... D.G. Martin
- District #8 Meeting, Niagara Falls, ON ..... J.E. Dexter
- Western Canada Section Meeting, Calgary, AB ..... J.E. Dexter

Canadian Grain Commission
- Grain Research Laboratory/Inspection Divisions
  - Workshop, Gull Harbor, MB ..... N.H. Barchuk, R.M. Clear, L.A. Cooke, J.K. Daun, J.E. Dexter, J.E. Kruger, D.E. LaBerge, B.A. Marchylo, R.R. Matsuo, V.J. Mellish, T.W. Nowicki, K.R. Preston, S.J. Symons, R. Tkachuk, K.H. Tipples, P.C. Williams

Canadian Phytopathological Society
- Regional Conference, Winnipeg, MB ..... R.M. Clear

Canola Industry Conference
- Saskatoon, SK ..... D.R. DeClercq

Codex Alimentarius Commission, FAO/WHO
Session in Washington, DC ..... R. Tkachuk

Commercial Seed Analysts Association of Canada
Annual Meeting, Winnipeg, MB ..... R.M. Clear
L.A. Cooke

Conference on Hard Winter Wheat Quality
Kansas City, MO ..... B.C. Morgan

Eastern Grain Standards Committee
1990 Meeting, Quebec, QC ..... K.H. Tipples

European Brewery Convention
Barley and Malt Group, Scientific/Technical Meeting
Utrecht, Netherland ..... A.W. MacGregor

Farm Progress Exposition
Regina, SK ..... L.J. Morris

Industrial Accident Prevention Association
Safety Conference, Toronto, ON ..... N.H. Barchuk

International Association for Cereal Science and Technology (ICC)
Executive Committee Meeting
Vienna, Austria ..... K.H. Tipples
1990 Congress, Vienna, Austria ..... R.R. Matsuo
K.H. Tipples
1990 Symposium, Moscow, USSR ..... K.H. Tipples

International Canola Conference
Atlanta, GA ..... J.K. Daun

International Commission on Occupational Health
Congress, Montreal, QC ..... N.H. Barchuk

International Electrophoresis Conference
Washington, DC ..... V.J. Mellish

International Gluten Workshop
Winnipeg, MB ..... J.E. Dexter
S.E. Gowan
D.W. Hatcher
J.E. Kruger
L.J. Macri
B.A. Marchylo
V.J. Mellish
K.R. Preston
R. Tkachuk

International Near-Infrared Symposium
Brussels, Belgium ..... P.C. Williams

International Seed Symposium
Ames, IA ..... B.A. Marchylo

International Standards Organization
TC34/SC4 Committee Meeting, The Hague, Netherlands ..... R. Tkachuk

International Symposium on Diffuse Reflectance Spectroscopy
Chambersburg, PA ..... R. Tkachuk
P.C. Williams

Institute of Brewing
Scottish Section Conference, Aviemore, Scotland ..... A.W. MacGregor

Institute of Food Technologists
Committee Meeting, Chicago, IL ..... M.E. Larmond

Jean De Clerck Chair IV
Meeting on Malting/Brewing Science, Leuven, Belgium ..... A.W. MacGregor

Labtech Inc. Notebook Seminar
Cleveland, OH ..... E.D. Lysenko
B.C. Morgan

Macdonald Nutrition Conference for the Feed Industry
McGill Universtiy, Montreal, QC ..... M.E. Larmond

Manitoba Agri-Forum
Winnipeg, MB ..... L.A. Cooke

Master Brewers' Association of the Americas
District Western Canada Annual Convention
Regina, SK ..... D.E. LaBerge

Microscopical Society of Canada
Annual Meeting, Halifax, NS ..... S.J. Symons

Oil Modification Workshop
Saskatoon, SK ..... J.K. Daun

Pesticide and Trace Organic Residue Analysts (Western Canada)
Annual Workshop, Vancouver, BC ..... T.W. Nowicki

Pittsburgh Conference on Analytical Chemistry
Chicago, IL ..... K.R. Preston

Near-Infrared Spectroscopy Workshop
Champaign-Urbana, IL ..... P.C. Williams

North Dakota/Minnesota Barley Tour ..... D.E. LaBerge

Spring Wheat Quality Advisory Council
Annual Meeting, Minneapolis, MN ..... K.R. Preston

Statistical Association of Manitoba
Annual Meeting, Winnipeg, MB ..... J.C. Babb

Statistical Society of Canada
Board of Directors Meeting, Quebec, QC ..... J.C. Babb

Symposium on Naturally Occurring Radionucleides in Agricultural Products
Orlando, FL ..... R. Tkachuk

Western Grain Standards Committee
1990 Meeting, Winnipeg, MB ..... K.H. Tipples

Zeiss Canada Imaging Workshop
Toronto, ON ..... S.J. Symons

Oral Presentations

At Canadian International Grains Institute

K.H. Tipples
Introduction to the Grain Research Laboratory *(presented twice)*

R.M. Clear
Mycology Techniques at the Grain Research Laboratory

L.A. Cooke
Seed Biology at the Grain Research Laboratory

J.K. Daun
Oilseed Grading Factors and Related End-use Product Quality

D.A. Daniel
Measurement of Sprout Damage

D.R. DeClercq, C.T. Thorsteinson and K.M. Clear
Oilseed Quality Analysis Techniques

J.E. Dexter
Effects of Grading Factors on End-use Quality of Canadian Wheat
Effects of Grading Factors in Wheat
Laboratory Milling Technology
Quality Characteristics of Western Canadian Wheats
Relation of Wheat Class and Grade to End-use Quality

L.G. Dushnicky
Electron Microscope Image Analysis

M.J. Edney
Feed Grain Research at the Grain Research Laboratory
Introduction to the Grain Research Laboratory

D.W. Hatcher
Wheat and Barley Variety Identification by HPLC

J.E. Kruger
Introduction to the Grain Research Laboratory

D.E. LaBerge
Canadian Malting Barley
Malting and Brewing Technology

J.J. Lachance
Laboratory Milling Technology

A.W. MacGregor
Effects of Degrading Factors on Barley Utilization

D.G. Martin
Laboratory Milling Technology

B.A. Marchylo and V.J. Mellish
Modern Instrumentation: Varietal Purity Control

B.A. Marchylo
Introduction to the Grain Research Laboratory

R.R. Matsuo
Effects of Degrading Factors on Durum Wheat Utilization
Measurement of Pasta Quality *(presented three times)*
Pasta Goods Manufacturing *(presented three times)*
Canadian Durum Wheat Quality
Quality Control at the Canadian Grain Commission

V.J. Mellish
Wheat Variety Identification by Electrophoresis

R.J. Wallis
Moisture Meter Calibration, Monitoring and Servicing

P.C. Williams
Modern Instrumentation: Measurement of Protein and Moisture by NIRS
Effects of Degrading Factors on Spring and Winter Wheat Utilization

At Conferences, Meetings and Seminars

K.H. Tipples
Canadian Research on Rapid Methods of Grain Quality Analysis *(presented three times)*
Japan Grain Research Council, Tokyo, Japan
Kansai Cereal Chemists, Osaka, Japan
1990 ICC Symposium, Moscow, USSR

M.E. Larmond
Animal Products in a Healthy Diet: Responding to Consumer Demands
Macdonald Nutrition Conference for the Feed Industry, Montreal, QC
Food Research in Agriculture Canada
Grain Research Laboratory Seminar, Winnipeg, MB

J.C. Babb
Data Transformation
Grain Research Laboratory Workshop, Winnipeg, MB
Regression Analysis
Lecture Series, Grain Research Laboratory, Winnipeg, MB

R.M. Clear
Mycology Seminar and Workshop for the Commercial Seed Analysts Association of Canada
Grain Research Laboratory, Winnipeg, MB
Seedborne Fungii
CSAAC, Annual Convention, Winnipeg, MB

L.A. Cooke
Grain Biology for Seed Analysts
CSAAC, Annual Convention, Winnipeg, MB

J.K. Daun
Overview of Canadian Canola Quality
International Canola Conference, Atlanta, GA
Relationship Between Seed Size and Quality Parameters in Canola and Rapeseed Varieties (Poster)
AOCS, Annual Conference, Baltimore, MD

D.R. DeClercq
Quality of 1990 Canadian Canola
Canola Industry Conference, Saskatoon, SK

J.E. Dexter
Development of Canada Prairie Spring Wheat
AOM, District No. 13 Meeting, Calgary, AB
Quality of the 1990 Canadian Wheat Crop
A Scenic and Scientific Look at the Milling and Baking Industry in Colombia
AOM, District No. 8 Meeting, Niagara Falls, ON
Removal of Tombstone Kernels from Fusarium Head Blight Infected Wheat on a Specific Gravity Table
Estimating Flour Refinement by Fluorescence Imaging
AACC, Annual Meeting, Dallas, TX
Canada Prairie Spring Wheat
CWB Informational Meetings in Four Western Canada Locations

L.G. Dushnicky
Application of Microscopy in the Grain Research Laboratory
Grain Research Laboratory Seminar, Winnipeg, MB

D.G. Gaba
Mycotoxins in Eastern Canadian Grains
CGC, Grain Inspection Division, Chatham, ON

D.E. LaBerge
Comparison of Malting and Brewing Properties of Commercial Samples of Canadian Barley with Commercial Samples of Barley from the USA, France and Australia
Canadian Wheat Board Seminar, Winnipeg, MB
MBAA, District Western Canada Meeting, Regina, SK
Canadian Grain Commission /Producer Seminars
Five Saskatchewan Locations

A.W. MacGregor
Current State of Research into Barley Carbohydrates and Enzymes
International Meeting on Malting, Brewing and Distilling, Aviemore, Scotland
The Structure of Barley and Malt
Eur. Brew. Conv., Barley and Malt Group, Utrecht, Netherlands

Starch Degrading Enzymes
Eur. Brew. Conv., Barley and Malt Group, Utrecht, Netherlands
Possible Effects of Barley Kernel Structure on Malt Quality
Heineken Breweries, Leiden, Netherlands
Improvements of the Amylolytic Activity of Malt
Jean De Clerck Chair IV Meeting, Leuven, Belgium
Quality-related Biochemical and Structural Changes in Developing and Germinating Barley Kernels
Dept. of Botany, University of Manitoba, Winnipeg, MB
Identification and Properties of a Beta-glucan Solubilase from Barley Kernels (Poster)
International Meeting on Malting, Brewing and Distilling, Aviemore, Scotland

B.A. Marchylo
The Structure of Cereal Grains
The Chemistry and Biochemistry of Malting
MBAA, Short Course on Brewing and Malting Science, Madison, WI
Quantitative Analysis of HMW Glutenin Subunits by RP-HPLC
International Gluten Workshop, Winnipeg, MB

D.G. Martin
A Tandem Buhler Laboratory Mill: Its Development and Versatility
AOM, Annual Conference, Orlando, FL

R.R. Matsuo
Textural Optimization of Spaghetti: Effects of Protein Content and Drying Temperature (Poster)
ICC, 1990 Congress, Vienna, Austria
Role of the Grain Research Laboratory in Quality Assurance and Market Support
Producer Seminars at Five Saskatchewan Locations
Introduction to the Grain Research Laboratory
Alberta Agriculture Wheat Seminars at Three Alberta Locations

V.J. Mellish
History of the Canadian Prairie Section No. 14 of the AACC (Poster)
AACC, Annual Meeting, Dallas, TX
Two-dimensional Electrophoresis of Wheat Proteins: A Comparison of Staining Procedures (Poster)
International Gluten Workshop, Winnipeg, MB
Two-dimensional Electrophoresis of Storage Proteins of Canadian Wheats (Poster)
International Electrophoresis Conference, Washington, DC

T.W. Nowicki
MDS Training Module: Pesticides
WHMIS Lecture, GRL, Winnipeg, MB

Publications

Scientific Papers

634 KRUGER, J.E., MARCHYLO, B.A.
Quantitative Analyses by RP-HPLC of Storage ProteiN Breakdown in Canadian Wheat Upon Germination.
Proc., Fifth Int. Sym. Pre-Harv. Sprout. in Cereals, 1989.

639 DEXTER, J.E., PRESTON, K.R., KILBORN, R.H., MARTIN, D.G.
The Effect on Residual Flour Quality of Removing Farina During Common Wheat Milling.
Cereal Chem. 67(1):39-46, 1990.

640 DEXTER, J.E., KILBORN, R.H., PRESTON, K.R.
The Effect of Formula Variations and Dough Development Method on Colombian Aliñado Bread Properties.
Cereal Chem. 67(1):46-52, 1990.

642 KIM HYUN-OCK, WILLIAMS, P.C.
Determination of Starch and Energy in Feed Grains By Near-infrared Reflectance Spectroscopy.
J. Agr. and Food Chem. 38(3):682-688, 1990.

643 KRUGER, J.E., MARCHYLO, B.A.
Analysis By Reversed-phase High-performance Liquid Chromatography of Changes in High Molecular Weight Subunit Composition of Wheat Storage Proteins During Germination.
Cereal Chem. 67(2):141-147, 1990.

644 TKACHUK, R., DEXTER, J.E., TIPPLES, K.H.
Wheat Fractionation on a Specific Gravity Table.
J. Cereal Science 11:213-223, 1990.

645 MACGREGOR, A.W., YIN, X.S.
Beta-glucan Solubilase from Barley - Further Observations.
Amer. Soc. Brew. Chem. 48(2):82-84, 1990.

646 EDNEY, M.J., MARCHYLO, B.A., MACGREGOR, A.W.
Structure of Total Barley Beta-glucan.
J. Instit. Brew. 97:39-44, 1991.

647 MARCHYLO, B.A., KRUGER, J.E., HATCHER,D.W.
Effect of Environment on Wheat Storage Proteins as Determined by Quantitative Reversed-phase High-performance Liquid Chromatography.
Cereal Chem. 67(4):372-376, 1990.

649 PANFORD, J.A., DEMAN, J.M.
Determination of Oil Content of Seeds By NIR: Influence of Fatty Acid Composition on Wavelength Selection.
J. AOCS 67(8):473-482, 1990.

650 CLEAR, R.M., PATRICK, S.K.
Fusarium Species Isolated From Wheat Samples Containing Tombstone (Scab) Kernels from Ontario, Manitoba and Saskatchewan.
Can. J. Plant Sci. 70:1057-1069, 1990.

651 DEXTER, J.E., MATSUO, R.R., KRUGER, J.E.
The Spaghetti-making Quality of Commercial Durum Wheat Samples With Variable Alpha-amylase Activity.
Cereal Chem. 67(5):405-412, 1990.

652 KILBORN, R.H., PRESTON, K.R., KUBOTA, H.
Description and Application of an Experimental Heat Sink Oven Equipped With a Loaf Height Tracker for the Measurement of Dough Expansion During Baking.
Cereal Chem. 67(5):443-447, 1990.

656 WILLIAMS, P.C.
Prediction of Wheat Kernel Texture in Whole Grains by Near-infrared Transmittance.
Cereal Chem. 68(1):112-114, 1991.

Miscellaneous Papers

M154 DEXTER, J.E., TIPPLES, K.H., MARTIN, D.G.
Predicting the Commercial Milling Potential of Canadian Western Red Spring Wheat from Experimental Milling Results.
Milling 182(8):9-11, 1989.

M155 TIPPLES, K.H.
Physical and Chemical Properties of Wheat as a Basis for Determination of End-use Quality.
Proc., 1989 ICC Sym., Chap.1:25-37.

M156 DEXTER, J.E., SYMONS, S.J.
Milling Efficiency: The Relevance of Flour Ash Content and Flour Color and the Potential Application of Near-infrared Reflectance Spectroscopy and Fluorescent Imaging.
Proc., 1989 ICC Sym., Chap.2:73-100.

M157 PRESTON, K.R., TIPPLES, K.H., MORGAN, B.C.
Prediction of Milling and Baking Characteristics of Canadian Wheat.
Proc., 1989 ICC Sym., Chap. 6:505-518.

M158 WILLIAMS, P.C., EL-HARAMEIN, F.J., SAYEGH, A., NACHIT, M., SRIVASTAVA, J.P.
Durum Wheat Utilization in West Asia/North Africa.
Proc., 1989 ICC Sym., Chap. 6:555-565.

M159 WILLIAMS, P.C.
New Applications of Near-infrared Technology.
Proc., 1989 ICC Sym., Chap. 5:391-409.

M160 KRUGER, J.E.
Monitoring for Sprout Damage in Cereals and Its Implications for End-product Quality in Cereals.
Proc., Fifth (1989) Int. Sym. Pre-harv. Sprout. Cereals: 321-328.

M161 MACGREGOR, A.W., DUSHNICKY, L.
Changes in the Stucture and Composition of Barley Kernels During Development.
Proc., 39th (1989) Conf., Roy. Austral. Chem. Inst.:80-82.

M162 MACGREGOR, A.W., MORGAN, J.E.
Properties of Alpha-amylases From Malted Barley.
Proc., 39th (1989) Conf., Roy. Austral. Chem. Inst.:70-74.

M163 WILLIAMS, P.C., SOBERING, D.C.
New Applications of Near-infrared Technology.
Proc., 39th (1989) Conf., Roy. Austral. Chem. Inst.:8-14.

M164 WILLIAMS, P.C., NAKKOUL, H.
Quality Screening and Evaluation in Pulse Breeding.
Proc., 39th (1989) Conf., Roy. Austral. Chem. Inst.:150-157.

M165 WILLIAMS, P.C., EL-HARAMEIN, F.J.
Prerequisites and Evaluation Technique for Flat Bread Baking.
Proc., 39th (1989) Conf., Roy. Austral. Chem. Inst.:90-95.

M168 CLEAR, K.M., DAUN, J.K., MILLS, J.T.
Effects of Frost Damage on Canola (Rapeseed) in Canada.
Gr. Cons. Int. de Rech. sur le Colza (GCIRC) - Bulletin (6):40-47, 1990.

M169 WILLIAMS, P.C., STEVENSON, S.G.
Near-infrared Reflectance Analysis: Food Industry Applications.
Trends in Food Science and Technology 1(2):44-48, 1990.

M170 KRUGER, J.E.
Instrumental Assessment of Sprout Damage in Wheat at Primary or Terminal Receival Points.
Cereal Foods World 35(9):935-939, 1990.

Other Publications

WYTINCK, R.G., ENTZ, M.H., STOBBE, E.H., CLEAR, R.M.
The Influence of Field Weathering on Seed Quality and Vigor of Katepwa Wheat and Heartland Barley.
Manitoba Agri-Forum, January, 1991.

Periodicals

Sixty-third Annual Report. 1989-90 Report of the Grain Research Laboratory

Cargo Bulletins

Red spring wheat editions are published in an English-French-German-Spanish version and an English-Chinese version (suffix"C").

Amber durum wheat editions are published in an English-French-German-Italian version.

255 Quality of Canadian Grain Exports 1989-90, Red Spring Wheat, second quarter, (Nov. 1 to Jan. 31)

256 Quality of Canadian Grain Exports 1989-90, Amber Durum Wheat, first and second quarters (Aug. 1 to Jan. 31)

257 Quality of Canadian Grain Exports 1989-90, Red Spring Wheat, third quarter (Feb. 1 to Apr. 30)

258 Quality of Canadian Grain Exports 1989-90, Red Spring Wheat, fourth quarter (May 1 to July 31)

259 Quality of Canadian Grain Exports 1989-90, Amber Durum Wheat, third and fourth quarters (Feb. 1 to July 31)

260 Quality of Canadian Canola and Flaxseed Cargoes, 1989-90 Crop Year

261 Quality of Canadian Grain Exports 1990-91, Red Spring Wheat, first quarter (Aug. 1 to Oct. 31)

Crop Bulletins

184 Quality of Western Canadian Wheat 1990

185 Quality of Western Canadian Feed Barley 1990

186 Quality of Western Canadian Malting Barley 1990

187 Quality of Western Canadian Canola 1990

188 Quality of Western Canadian Flaxseed 1990

189 Quality of Canadian Soybean 1990

GRL Digest (Newsletter)

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** Career-oriented Summer Employment Program (COSEP).